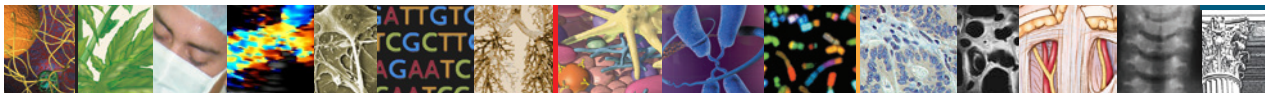

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Perspective

Preparing for the Next Harvey, Irma, or Maria — Addressing Research Gaps

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Extreme events often cast in bold relief what we do and don't know about medicine and public health. In recent weeks, three hurricanes, each characterized by "unprecedented" features, have illuminated our knowledge gaps regarding the consequences of disasters and their mitigation.

Hurricanes Harvey, Irma, and Maria affected large populations and caused widespread destruction, resulting in massive resource losses and economic costs. We know quite a bit about the likely consequences of these storms. As winds diminish and rescues proceed, the response focus rapidly shifts toward reestablishing essential infrastructure. Top mitigation priorities include distributing survival necessities, restoring power, and bringing hospitals back on line. These actions minimize short-term health threats such as patients with chronic health conditions decompensating or losing access to life-sustaining treatments and populations' exposure to deadly heat stress and waterborne and vectorborne diseases. Performed effectively, they also forestall longer-term mental health consequences.

We know that a substantial proportion of people who were directly exposed to life-threatening storm hazards, were physically injured, lost a loved one, or lost substantial resources may report increased symptoms of mental disorders in the coming months, with post-traumatic stress disorder (PTSD) as the sentinel condition.[1] PTSD and depression may also develop in storm-affected people who were not directly exposed, albeit at lower rates.

A stepped-care approach includes a number of phased elements. During the disaster impact, these include moving people to safety, providing survival needs, and reuniting separated family members. In the immediate aftermath, it's important to maintain or restore care, provide access to medications for persons with preexisting conditions, meet short-term practical needs, and assess hazard exposures and resource losses. Over the longer term, it's essential to maintain ongoing surveillance, and referral as needed, for the onset of psychopathology in persons who've been injured, bereaved, or experienced traumatic exposures or severe losses. Rapid restoration of social and economic function contributes substantially to population health and well-being after these events.[2]

The closeness in time and space of these storms has conflated them in the public narra-

tive. But their divergent hazard profiles highlight some knowledge gaps. Harvey was primarily a flood event, unleashing 33 trillion gallons of water, setting a U.S. rainfall record, damaging 100,000 homes, and rivaling Hurricane Katrina as the costliest U.S. natural disaster. Irma was a windstorm that maintained maximum wind speeds of at least 180 mph for 37 consecutive hours, longer than any other tropical cyclone in history.[3] Maria's trajectory produced back-to-back catastrophes as its eyewall tracked across Dominica and then bisected Puerto Rico.

Population-protective measures varied by storm. Evacuation from Houston was logistically impossible during Harvey, which trapped many people in flooded neighborhoods. Evacuation from Dominica and Puerto Rico was geographically impossible during Maria, so many people were subjected to the full force of hurricane winds. In contrast, Irma triggered mass evacuations throughout the Florida peninsula and southeastern United States — actions that, though stressful, moved people away from harmful forces.

Effects on health care infrastructure also varied. During Harvey, some Houston-area hospitals and extended care facilities were flooded, with patients and residents inside. Despite challenges, including flooded highways obstructing ambulance operations, well-rehearsed emergency plans helped ensure that no storm-related deaths occurred in area facilities.

As Irma approached, three hospitals in the Florida Keys and several in south Florida evacuated their patients to other facilities. Within days after Irma passed, operations were returning to normal for hospitals statewide, with only Fisherman's Hospital in Marathon Key closed because of storm damage. However, Irma produced widespread power outages, and in one nursing home in Broward County, 12 patients died, apparently because of heat stress.

Maria's impact on Puerto Rico substantially damaged hospitals and their capacity to protect patients' well-being. On September 26, a total of 58 of Puerto Rico's 69 hospitals had neither power nor fuel. One week later, the situation was worsening, as most of the island still lacked power and the few operational hospitals were running on generators and rationing dwindling supplies of diesel fuel. Most hospitals had no air conditioning, water was in short supply, and medications were running out.

These differences highlight limitations of our understanding of disasters' health consequences. For instance, our assessment of the types and "dosage" of potentially traumatizing hazard exposures experienced by disaster-affected populations lacks the necessary granularity to inform the development of useful interventions. Our approach of creating big-tent categories to define high-risk populations lacks precision and utility for identifying and addressing survivors' needs. Yet even residents in close proximity to one another can experience highly disparate exposures. For example, proneness to severe flooding in Houston varied by residential areas that are segmented by race and socioeconomic status.

A related lesson is unfolding in Dominica and Puerto Rico: when an entire population experiences a powerfully traumatizing exposure, the severity of physical and psychological harm will be codetermined by the extremity of hardships in the aftermath and the timeliness and effectiveness of disaster response.

Another gap is that our geospatial mapping of infrastructure vulnerabilities doesn't incorporate the human geography of disaster risk. So, for example, only 17% of people in the eight counties hit hardest by Harvey had flood insurance, largely because many flooded homes were outside the high-flood-risk boundaries of outdated floodplain maps and didn't qualify for coverage.

We have limited understanding of the behavior of disaster survivors in relation to their receipt of aid, though we know that only a minority access available resources. Harvey and Irma revealed a new, policy-driven barrier to seeking care: citizens with undocumented family members were afraid to evacuate or seek shelter.

The science of connecting survivors to appropriate postdisaster services remains in its infancy. In Puerto Rico, where Maria obliterated local emergency-response capacity, survivors, geographically isolated by storm damage and deprived of communications, waited seemingly interminable periods for help to arrive. We suspect that a continuum of behaviors will emerge after this hurricane, ranging from tragic to resilient and heroic.

Perhaps the greatest barrier to systematically addressing these gaps is the episodic nature of disasters. Natural disasters capture our attention during the warning, impact, rescue, and response phases. But then media and scientific attention moves on. This sporadic focus leads us to

fall short on answers when the next events occur.

The preferable alternative would be to tackle knowledge gaps now and invest in research that can prepare us to handle the next hurricanes. Perhaps this triplet of devastating storms will motivate public health professionals to creatively harness science to plug these gaps in understanding.

Centrally, we need to lay the groundwork to adequately characterize predisaster circumstances in order to establish baseline data for defining disaster-related consequences. Although many disasters are not specifically predictable, we can identify high-risk locales. Selective investment in cohorts in these areas and development of robust baseline measures may get us to this goal sooner than we think.

Disaster research generally, and characterization of at-risk populations specifically, must be made more precise by combining behavioral, ecologic, and biologic information. Such a transdisciplinary endeavor, though consistent with national trends as exemplified by the All of Us approach,[4] would represent a quantum leap in sophistication, advancing the field.

In a world of globally networked risks, the consequences of disasters are products of complex systems.[5] We cannot understand consequences through a simple exposure–outcome paradigm; we need to invest in systems-science methods for examining the interrelated factors influencing populations' health after these events.

A preventive approach to disasters, exemplified by international research on disaster risk reduction — which focuses on anticipating vulnerabilities, creating resilience, and mitigating consequences — is ripe for application by public health officials. Effective disaster prevention and mitigation initiatives have demonstrated a favorable economic return on investment, transforming disaster response from reactive to proactive and protective.

This is a teachable moment that should stimulate investment in proposals for filling our knowledge gaps. These storms have caused preventable human harm and produced destruction on a scale that will require extraordinary expense for recovery and reconstruction. For example, all three storms highlighted the frailty of electrical power grids, which requires immediate redress. Moreover, the lack of preparedness for reaching isolated communities in Puerto Rico is a critical omission that can inform future disaster planning.

The relatively few deaths from Harvey and Irma demonstrate that we have learned from previous disasters, but the prolonged threat to life in Puerto Rico stands as a warning that more must be done. The impact of these hurricanes provides a compelling rationale for investing in the science that can better prepare us for the next large-scale traumatic event.

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